REMARKS

Applicants have carefully considered the November 2, 2005 Office Action, and the comments that follow are presented in a bona fide effort to address all issues raised in that Action and thereby place this case in condition for allowance. Entry of the present Request for Reconsideration is respectfully solicited. It is believed that this response places this case in condition for allowance. Hence, prompt favorable reconsideration of this case is solicited.

Claims 1, 3 and 4 were rejected under 35 U.S.C. § 102(b) as being anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over EP 1063542 A1, hereinafter the "'542 application". Applicants respectfully traverse.

Applicants again submit that the Examiner's rejection under is improperly based upon the combination of the thickness of the embodiment shown in Fig. 7 and the longitudinal and transversal lengths of a separate embodiment shown in Fig. 10 of the '542 application. Reconsideration and withdrawal of the rejection over the '542 application in view of the following arguments are respectfully solicited.

In response to Applicants' arguments submitted on August 17, 2005, the Examiner at pages 2-3 of the final Office action, asserted that both embodiments of the '542 application (Fig. 7 and 10) require a bobbin having a cylinder diameter upon which the 10 km of DCF is wound. In addition, the Examiner stated that it would not be necessary to wind the DCF at a smaller diameter, but instead, a bobbin having a smaller width or thickness could be used. Applicants respectfully submit that the Examiner's characterization of the '542 application are technically incorrect.

An accommodating volume for fiber is determined by a width and a horizontal size. Assuming that a length of an optical fiber is constant, i.e. a volume of the entire optical fiber is constant, the horizontal size should be increased in the case of reducing the bobbin width. This

situation cannot reduce the volume of the housing. In order the reduce the horizontal size without increasing the bobbin width, it is necessary to reduce a wounding diameter of the bobbin. The Examiner's attention is respectfully directed to the accompanying drawings A and B which illustrate Applicants' position. See **Appendix A**. Considering the fact that the flange size (200 mm diameter) of bobbin 2 is larger than a shorter side (130 mm) of the housing 80, it is clear that the bobbin size and the housing size cannot be simply combined.

The Examiner's comments are based on the use of the housing or a modification thereof in the '542 application. However, it is clear that the housing of the '542 application does not realize a smaller housing volume, as described above. In order to reduce a housing volume, the DCF should be wound to a smaller diameter. The present claimed subject matter is characterized by suppressing a volume of the dispersion compensator by winding the DCF to a smaller diameter. At the time that the DCF is wound to a smaller diameter, its transmission loss does not increase, or at least can be suppressed to a minimal increase.

With respect to claims 3-4, at page 4 of the final Office action, the Examiner asserted that the '542 application discloses the connection loss and bending loss as claimed. Applicants respectfully request reconsideration of the Examiner's position in view of the following remarks and accompanying reference (Bent Edvold, et al., "New Dispersion Compensating Fiber Modules with Full Slop Compensation, High FOM, and Ultra Low PMD", Tech, Proc. of NFOEC99, Vol. 2, pp. 473-479 (1999). See **Appendix B**. Fig. 8 of the Edvold reference describes a total connection loss of 1.6 dB with respect to a dispersion of -95 ps/nm/km and a dispersion slope of -0.33 ps/nm^2/km (RDS = Slope/Dispersion = 0.0035), and further, a total connection loess of 1.4 dB with respect to a dispersion of -100 ps/nm/km and a dispersion slope of -0.22 ps/nm^2/km (RDS = 0.0022). The characteristics of DCF of the '542 application, having a dispersion of -100 ps/nm/km and a

dispersion slope of -0.29 ps/nm^2/km at a wavelength of 1550 nm, is very similar to those of Fig. 8 of the Edvold reference. Therefore, it can be readily seen that a connection loss of DCF of the '542 application is also similar to that of Fig. 8 of the Edvold reference. That is, the insertion loss of the dispersion module of the '542 application would be 5.4 dB of more, because the fiber loss in the DCF of the '542 application is 4dB (= transmission loss of 0.4 dB/km x fiber length of 10 km). In addition, it can be seen that the total connection loss of the '542 application is 1.4 dB or more, when considering Fig. 8 of the Edvold reference. In other, words, the insertion loss becomes 5.4 dB or more as the sum of the fiber loss of 4dB and the connection loss of 1.4 dB or more.

With regard to the bending loss of the '542 application, as described above, the dispersion compensator of the '542 application does not realize the claimed housing volume, because the reduction of a winding diameter for the DCF is necessary to reduce a housing volume. The step of reducing a winding diameter causes an increase of bending loss and, therefore, an insertion loss in the dispersion compensator further increases. As an example, the Examiner's attention is directed to Lars Gruner-Nielson, et al., "Dispersion Compensating Fibers", Optical Fiber Technology, Vol. 6, pp. 164-180 (2000). See **APPENDIX C**. In Fig. 8 of the Gruner-Nielson reference, a bending loss increases by one digit whenever a winding diameter of the DCF is small at 10 mm.

Accordingly, for the reasons set forth above, Applicants submit that the Examiner's rejection under 35 U.S.C. § 102(b) as being anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over the "'542 application is not legally viable and should be withdrawn.

Claims 8, 10, 11, 15, 17, 18, 22, 24 and 25 were rejected under 35 U.S.C. § 103(a) as being unpatentable over the '542 application. Applicants respectfully traverse the rejection for the reasons outlined below.

As described above, it is necessary to wind the DCF to a smaller diameter in order to reduce a housing volume. Therefore, the fact that a bending loss of the DCF is low is essential to module downsizing. In contrast, the '542 application simply teaches a bending loss of 1dBm at a diameter of 20 mm. Therefore, Applicants submit that the Examiner's assumption that a small module can be realized by using this DCF is speculative at best. Accordingly, Applicants submit that the Examiner has not established a *prima facie* basis to deny patentability to the claimed invention under 35 U.S.C. § 103 for lack of the requisite factual basis and lack of the requisite realistic motivation. The Examiner is requested to reconsider and withdraw the rejection under 35 U.S.C. § 103(a).

Claims 2, 5, 6, 9, 12, 13, 16, 19, 20, 23, 26, 27 and 29-32 were rejected under 35 U.S.C. § 103(a) as being unpatentable over the '542 application and further in view of EP 1130428 A1, hereinafter the "'428 application". Applicants respectfully traverse the rejection for the reasons outlined below.

At page 5 of the final Office action, the Examiner stated that transmission loss can be lowered by simply selecting an appropriate value of Δ1. Applicants respectfully submit that the Examiner's statement is not accurate. Since the '428 application teaches at col. 5, lines 5-16 that (1) a dispersion becomes large when Δ1 increases and (2) that Δ1 is increased by increasing the dopant amount of GeO_2 causes an increase of transmission loss. The Δ1 (=2.5%) and the dispersion (-200 ps/nm/km) of the DCF of the '428 application are larger than the Δ1 (=2.1%) and the dispersion (-100 ps/nm/km) of the DCF in the '542 application. As such, a transmission loss of the '428 application would also be larger than that of the '542 application. Thus, the low insertion loss of the present claimed subject matter is not taught or suggested by the applied

references. The Examiner is, therefore, requested to reconsider and withdraw the rejection under 35 U.S.C. § 103(a).

Claims 7, 14, 21, 28 and 33 were objected to as being allowable if recast in independent form. Applicants submit that for the reasons outlined above, claims 1-33 are in condition for allowance. Moreover, Applicants note the Examiner's Statement of Reasons for Allowance included on page 10 of the Office action. Entry of that Statement into the record should not be construed as any agreement with or acquiescence by Applicants in the reasoning stated by the Examiner. Applicants positions on the issues appear in Applicants' response. The Statement of Reasons for Allowance should not be used to interpret the cited claims, particularly to the extent if any that the Statement of Reasons for Allowance may differ from the express language of the claims and/or Applicants' positions on patentability of those claims. It is respectfully submitted that the allowed claims should be entitled the broadest reasonable interpretation and broadest range of equivalents that are appropriate in light of the language of the claims, the supporting disclosure and Applicants' prosecution of the claims, without reference to the Statement of Reasons for Allowance.

It is believed that pending claims 1-33 are now in condition for allowance. Applicants therefore respectfully request an early and favorable reconsideration and allowance of this application. If there are any outstanding issues which might be resolved by an interview or an Examiner's amendment, the Examiner is invited to call Applicants' representative at the telephone number shown below.

To the extent necessary, a petition for an extension of time under 37 C.F.R. 1.136 is hereby made. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account 500417 and please credit any excess fees to such deposit account.

Respectfully submitted,

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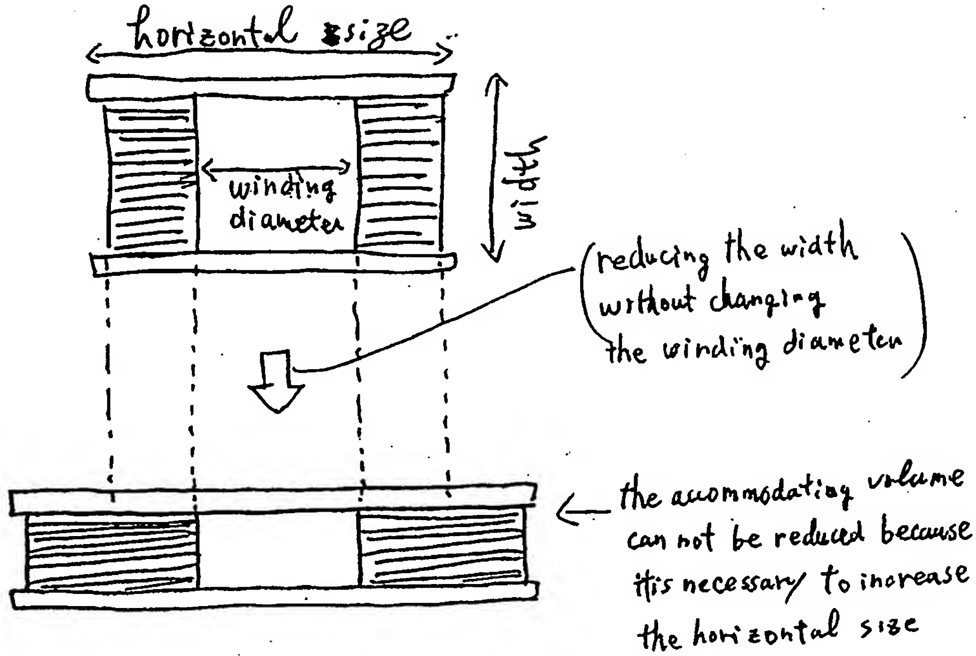
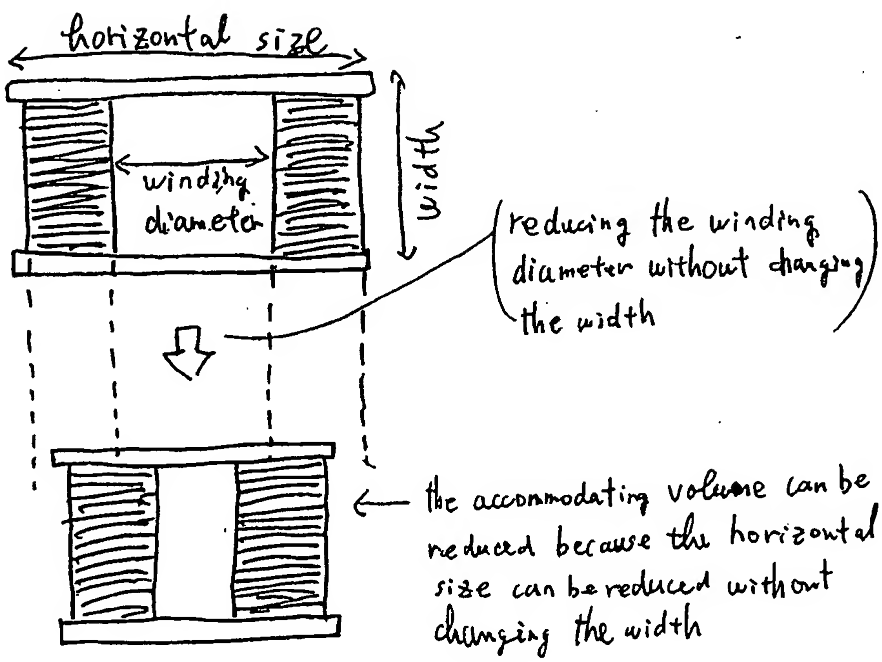
Drawing A



Drawing B



Tech. Proc. of NFOEC 99 Vol. 2 . pp. 473~479

参考文献 1

NEW DISPERSION COMPENSATING FIBER MODULES WITH FULL SLOPE COMPENSATION, HIGH FOM, AND ULTRA LOW PMD

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Introduction

To realize 10 Gbit/s WDM transmission on existing links consisting of standard single mode fiber (SSMF) dispersion compensation is required. At 40 Gbit/s dispersion becomes even more critical and dispersion compensation in a broad wavelength range, i.e., full dispersion slope compensation, is required to achieve sufficiently low variation of the dispersion over the transmission wavelength range[1].

Introduction of the optical amplifier overcame the problem of attenuation in optical fibers by providing amplification in the 1530-1560 nm window without the need for regeneration of the optical signal. However, as SSMF were originally designed for use at 1310 nm, transmitting in the 1550 nm window results in a large amount of dispersion. Dispersion can be defined as the variation of the propagation delay through the fiber with wavelength because the effective index of refraction varies with wavelength. The dispersion in single mode fibers is an interplay between the material dispersion of silica and the waveguide dispersion caused by the change in the waveguide properties of the fiber with wavelength. In SSMF the two contributions cancel each other at ~1310 nm also known as the zero dispersion wavelength. At 1550 nm the dispersion of SSMF is ~17 ps/km/nm. Figure 1 shows the attenuation and dispersion of various types of transmission fibers.

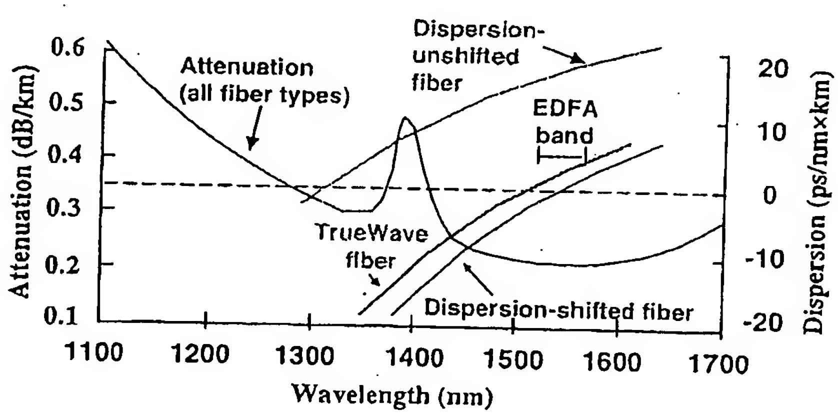

Figure 1: Attenuation and dispersion spectra for dispersion unshifted fiber (SSMF), dispersion shifted fiber and TrueWave fiber (NZ-DSF).

If the laser used for transmission is modulated directly the wavelength varies across the pulse which is converted to a variation in the propagation delay of different parts of the pulse, i.e. a distortion of the pulse. Using external modulation can minimize the problem, but as bitrates increase the signal bandwidth due to modulation can result in significant dispersion. The table shown in Figure 2 shows the practical dispersion limits without dispersion compensation for SSMF and NZ-DSF.

Bit rate	SSMF	NZ-DSF
2.5 Gbit/s	640 km	4400 km
10 Gbit/s	50-100 km	300-500 km
40 Gbit/s	~5 km	20-30 km

Figure 2: Practical transmission limits without dispersion compensation

Dispersion Compensation

As seen from Figure 2 the problems caused by dispersion can be minimized by using NZ-DSF, however this is not an option for the already installed fiber base of SSMF. The Dispersion Compensating Fiber (DCF) is designed to compensate for the dispersion in SSMF and is well suited to upgrade existing fiber links to 10 Gbit/s or more. The fiber works by introducing a large negative dispersion to balance the positive dispersion of the SSMF, i.e., the wavelength components that are propagating faster in the SSMF are delayed in the DCF and vice versa. If the dispersion D and length L of the DCF and SSMF is denoted by subscripts DCF and SSMF, respectively, then the length of the DCF needed to cancel the dispersion of the SSMF is:

$$L_{DCF} = \frac{D_{SSMF}}{-D_{DCF}} \cdot L_{SSMF}$$

For a typical span of 80 km of SSMF and a typical DCF dispersion of -100 ps/nm/km, 13.6 km of DCF is needed to obtain complete dispersion compensation. However, the DCF also introduces additional attenuation in the link. The amount of additional attenuation depends on the attenuation coefficient α_{DCF} of the DCF, but also on the dispersion of the DCF, as a large negative dispersion implies that only a short length of DCF is needed. Thus a Figure of Merit (FOM) of the DCF can be defined as

$$FOM = \frac{-D_{DCF}}{á_{DCF}}$$

The large negative dispersion of the DCF is accomplished by tailoring the waveguide dispersion. This can be accomplished by a simple step index design: By decreasing the core diameter and increasing the core index the zero dispersion wavelength is shifted from 1310 nm towards higher wavelengths. By shifting the zero dispersion beyond 2 μm large negative dispersion at 1550 nm is obtained. However, by decreasing the core diameter the bend sensitivity is also increased indicating that there is a practical limit as to how much negative dispersion can be accomplished.

There is a disadvantage of the simple step index design DCF described above. By shifting the zero dispersion wavelength upward negative dispersion at 1550 nm is obtained, but the slope of the dispersion curve of this type of DCF is positive just as the SSMF. Thus, compensation is achieved at 1550 nm but the dispersion slope of the link is increased which means that channels placed at the edges of the EDFA window

can experience too much dispersion. The solution to this problem is to use a more sophisticated refractive index profile of the DCF to obtain a negative dispersion slope[2, 3]. A typical refractive index profile of a negative slope DCF is shown in Figure 3.

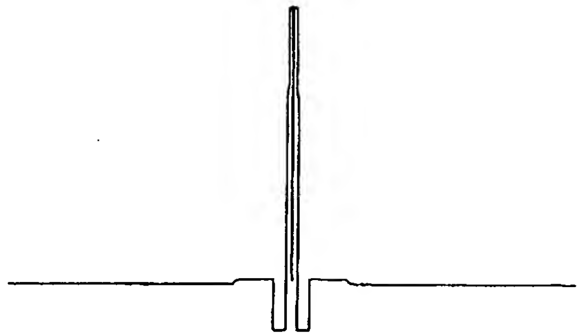

Figure 3: Typical refractive index profile of a negative slope DCF compared to a standard single mode fiber (SSMF). The refractive index of the core is ~5 times that of a SSMF.

By using a DCF with a negative slope, in addition to obtaining zero net dispersion at 1550 nm the difference in total dispersion between channels at the edges of the transmission window is also decreased. This makes negative slope DCF ideal for WDM transmission.

Today DCF is being deployed in commercial WDM systems. Statistics for production of more than 10000 km of DCF was presented at OFC'98[2]. Typical values for the important parameters of negative slope DCF are shown in Figure 4.

Property	Typical value
Dispersion	-100 ps/(nm·km)
Figure of merit	200 ps/(nm·dB)
Attenuation	0.50 dB/km
Dispersion slope	-0.22 ps/(nm^2·km)
Mode field diameter	5.2 μm

Figure 4: Typical values for negative slope DCF parameters.

The DCF is usually deployed at central offices together with EDFAs and control electronics. Therefore, the DCF has to be packaged into a Dispersion Compensating Module (DCM) with the correct length of DCF to compensate for e.g. 40, 60 or 80 km of SSMF. The DCF has to be wound on a compact spool and connectorized with standard SSMF. This involves splicing the DCF to SSMF with low loss, which is not an easy task as the mode field diameter of the DCF is very small compared to that of the SSMF. Special techniques for obtaining low splice loss between DCF and SSMF have been developed[4] yielding splice losses of ~0.5 dB.

Even though the negative slope DCF also compensates for the slope of SSMF, it is not fully slope compensating. Full slope compensation becomes increasingly important as 40 Gbit/s systems are being developed. As seen from Figure 2, the amount of residual dispersion that can be tolerated in 40 Gbit/s transmission is very small. In practical deployment the dispersion of the transmission fiber is only known within a certain interval and therefore there are two uncertainties: the residual dispersion <u>and</u> the dispersion slope. If the link can be fully compensated for the dispersion slope, the second uncertainty is removed. The important parameter for compensation of the dispersion slope is the *relative dispersion slope*. A compensated link will look as shown in Figure 5.

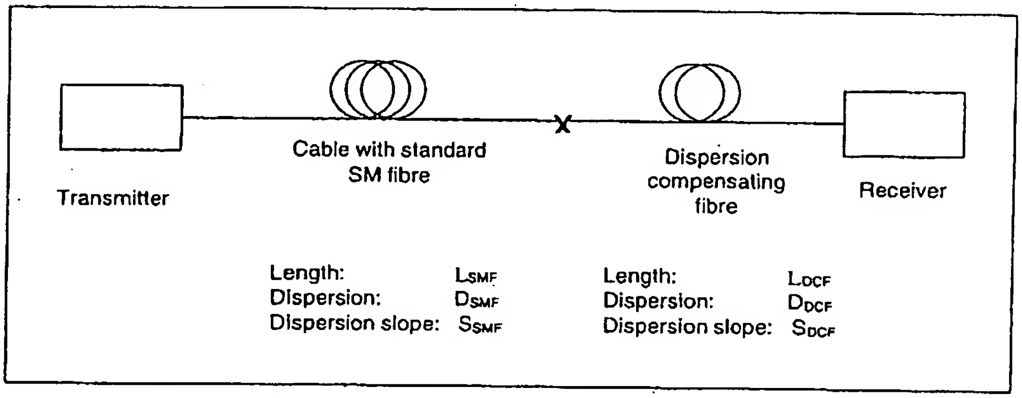

Figure 5: Schematic drawing of a dispersion compensated link.

The total dispersion and the total dispersion slope of the link shown in Figure 5 is:

$$D_T = D_{SMF} L_{SMF} + D_{DCF} L_{DCF}$$
$$S_T = L_{SMF} S_{SMF} + L_{DCF} S_{DCF}$$

If the link is fully dispersion compensated, then D_T=0. In this case, the condition for simultaneous compensation of dispersion slope is (S_T=0):

$$RDS_{DCF} = RDS_{SMF}$$

RDS is the *relative dispersion slope*, defined as:

$$RDS = \frac{S}{D}$$

In a system with full dispersion compensation, but only partial slope compensation, the total slope of the system can be calculated as:

$$S_T = L_{SMF} S_{SMF} (1 - DSCR)$$

DSCR is the Dispersion Slope Compensation Ratio, which is defined as:

$$DSCR = \frac{RDS_{DCF}}{RDS_{SMF}} = \frac{\dfrac{S_{DCF}}{D_{DCF}}}{\dfrac{S_{SMF}}{D_{SMF}}}$$

The SSMF typically has a dispersion of 17 ps/nm/km and a slope of 0.058 ps/nm^2/km at 1550 nm, yielding a RDS of 0.058/17 nm^{-1}=0.0034 nm^{-1}. As seen from Figure 4, the DCF has a relative slope of 0.22/100 nm^{-1}=0.0022 nm^{-1}, i.e., it has a DSCR of 65% which means that it compensates for ~2/3 of the dispersion slope of SSMF.

Full slope compensating DCF

The need for better dispersion compensation in 40+ Gbit/s systems, has led to the development of a full slope compensating DCF[5]. Figure 6 shows the measured dispersion versus wavelength for a link of standard SMF and full slope compensating DCF. In Figure 6, the dispersion is given as the dispersion per km of standard fiber, as the dispersion compensating fiber is normally applied as a module at the central office.

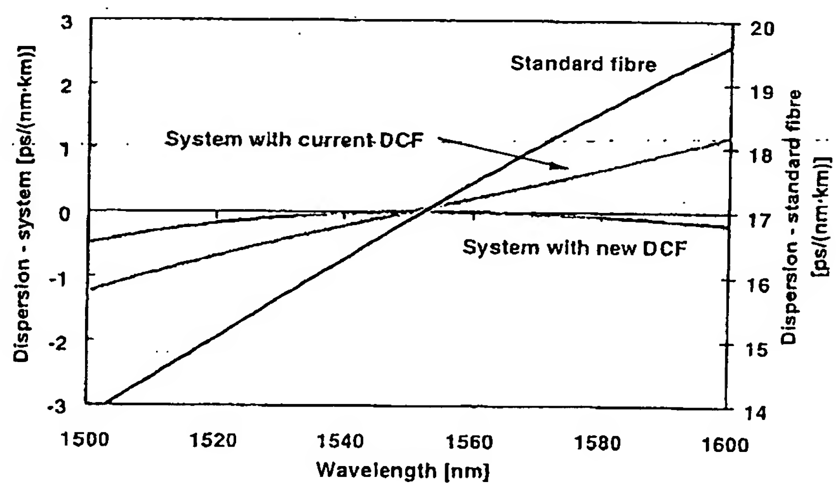

Figure 6: Measurement of the dispersion characteristics of a link comprising of SSMF and full slope compensating DCF. The dispersion is normalized with the length of the SSMF. The dispersion is compared to a system with the current DCF and to a system without DCF (right scale).

A number of full slope compensating DCFs has been manufactured. The distribution of the RDS for these fibers is shown in Figure 7.

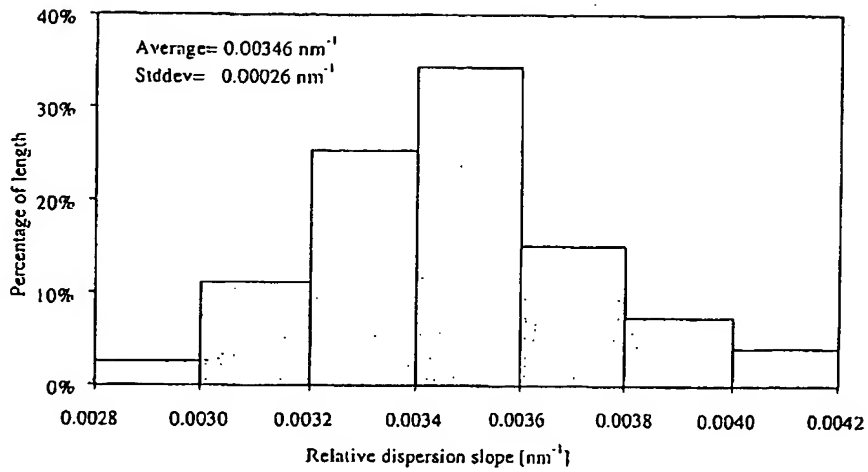

Figure 7: Distribution of relative dispersion slope (RDS) for the manufactured full slope compensating DCFs.

The typical characteristics of the full slope compensating DCF are compared to the standard DCF in Figure 8. It is seen that the dispersion of the new DCF is a little higher than the standard DCF, which results in a Figure of Merit that is a little lower. Also, the splice losses are a little higher than for the standard DCF.

	New DCF	Standard DCF	
RDS	0.0035	0.0022	nm^{-1}
FOM	190	200	ps/(nm·dB)
Attenuation 1550 nm	0.50	0.50	dB/km
Dispersion 1550 nm	-95	-100	ps/(nm·km)
PMD	0.08	0.08	ps/sqrt-km
Total splice loss*	1.6	1.4	dB

* All splices and one connector-connector interface loss on a module

Figure 8: Typical values for the new DCF compared to the standard DCF.

As seen from Figure 8, the PMD of the DCF is not much higher than SSMF even though the DCF is a small core, high index fiber design. The low PMD values have been achieved by careful tuning of the MCVD process to obtain very low core ovality combined with optimizing the oscillatory twist during draw. The requirements for PMD are also tightened when increasing the bitrate and PMD is much more difficult to compensate than chromatic dispersion. The distribution of total PMD for DK-80 modules (-1360 ps/nm @1550 nm) is shown in Figure 9.

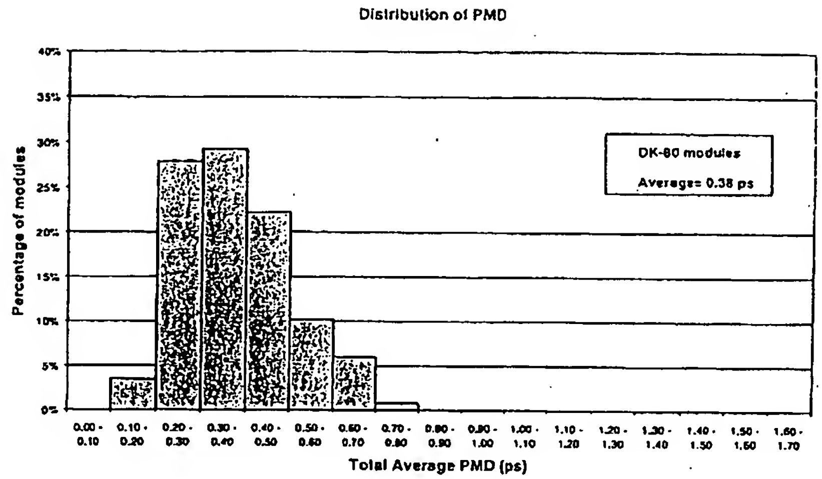

Figure 9: Distribution of total PMD for DK-80 modules (-1360 ps/nm @1550 nm).

Conclusion

As the demand for bandwidth increases, dispersion compensation in optical transmission systems becomes important. The majority of the installed fiber base consists of SSMF and dispersion compensating modules can be used to upgrade these systems to 10+ Gbit/s WDM transmission. Today, DCMs are being deployed in commercial systems. In future systems operating at 40 Gbit/s dispersion becomes even more critical and DCF capable both dispersion and full dispersion slope compensation has been developed. To obtain full compensation of the dispersion slope in a dispersion compensated system, the relative dispersion slope (RDS) of the DCF must match the RDS of the transmission fiber. A number of full slope compensating DCFs has been produced with an average RDS of 0.0035 nm^{-1}, which matches the typical RDS of SSMF of 0.0034 nm^{-1}. Also, improving the oscillatory twist during fiber draw has reduced the PMD of the DCF, yielding an average PMD of only 0.08 ps/sqrt-km.

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参考文献 2

Invited Paper

Dispersion Compensating Fibers

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The basic principles for use of dispersion compensating fibers (DCF) are reviewed, including definition of figure of merit and condition for dispersion slope compensation. The main design features of a triple-cladding index profile design are examined theoretically and experimentally. Production results are presented for three types of DCF. It is shown that polarization-mode dispersion can be reduced by introducing oscillatory twist into the fiber. The splice loss between DCF and standard fibers is shown to be reducible by use of a special intermediate fiber. Two methods for measuring the nonlinear effective area of DCF are compared and good agreement is found. Measurement results for the nonlinear refractive index n_2 are reported. The nonlinear coefficient n_2/A_{eff} of DCF is found to be a factor of 5 higher than that on standard single-made fibers. The macrobending resistance of DCF is examined and found to be comparable with that of standard fibers. The microbending resistance of DCF is found to be better than that of standard fibers. Finally, positive results from a cabling experiment with DCF are reported.

INTRODUCTION

A large number of the optical fiber cables installed today make use of nonshifted single-mode fibers, i.e., fibers with zero dispersion wavelength at 1310 nm and a dispersion of about 17 ps/(nm · km) at 1550 nm. Nowadays, wavelengths around 1550 nm are the preferred transmission window. This is because the fiber loss has its minimum close to this wavelength and because the erbium-doped fiber amplifier operates in this wavelength region. For bit rates up to 2.5 Gbit/s problems related with the dispersion can be solved by use of narrowband transmitters. When the bit

1068-5200/00 $35.00

TABLE 6
Properties of the Tested Standard Matched Cladding Fibers

Fiber	Cutoff (nm)	Mode field diameter (μm)
SSMF A	1299	9.11
SSMF B	1254	9.32
SSMF C	1188	9.55

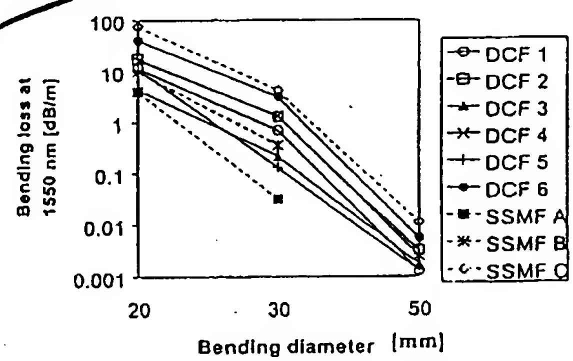

FIG. 8. Results of the macrobending test at 1550 nm.

The wavelength dependence of the bend loss for a bend diameter of 50 mm is shown in Fig. 9 for the most bend-sensitive DCF and SSMF fibers. Very different wavelength dependence is observed for the two fiber types. The DCF has a steep wavelength dependence compared to the SSMF.

The microbending resistance of the fibers has been evaluated using the test method IEC 793-1-C3C [23]. The fiber is placed under load in a loop of diameter

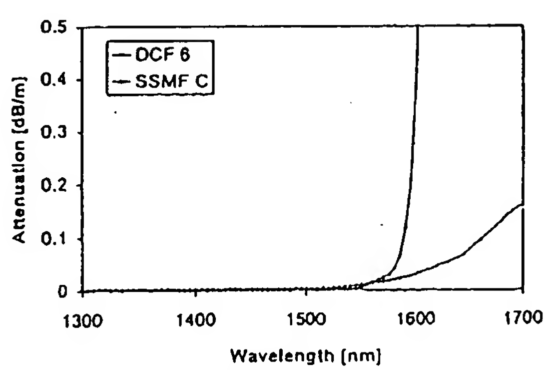

FIG. 9. Macrobending loss results for a diameter of 50 mm.